Wage Bargaining and Labor Market Policy with Biased Expectations

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Abstract

Recent research documents mounting evidence for sizable and persistent biases in individual labor market expectations. This paper incorporates subjective expectations into a frictional labor market model and studies the implications of biased expectations for wage bargaining, firms' vacancy creation and worker flows. Contrary to the rational expectations case, in the presence of biased expectations the specific assumption about the frequency of wage bargaining becomes crucially important for equilibrium outcomes. When the standard assumption is applied, whereby wages are negotiated every period, then the model generates counterfactual predictions regarding the effect of bias on wages. Instead, when the bargaining occurs only infrequently then the model's predictions are in line with the empirical evidence. As an extension, we also allow firms to have biased beliefs and we establish that the size of the bias does not matter per se, but only the difference between workers' and firms' bias.

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1 Introduction

A large part of modern labor market research relies on models which incorporate labor market frictions into a macroeconomic framework. These models emanate from the pioneering work of Diamond (1982), Mortensen (1982), and Pissarides (1985) and they have been used to study a wide variety of topics in labor economics. This includes, for example, the study of worker and job flows over the business cycle (Merz, 1995; Shimer, 2005; Christiano et al., 2016) and across countries (Marimon and Zilibotti, 1999; Pries and Rogerson, 2005; Ljungqvist and Sargent, 2007), as well as the welfare analysis of labor policies and institutions (Acemoglu and Shimer, 1999; Flinn, 2006; Krusell et al., 2010), and the role of worker and firm heterogeneity for aggregate outcomes (Mortensen and Pissarides, 1994). See Rogerson et al. (2005) and Rogerson and Shimer (2011) for surveys of these works.

The standard approach in this literature – as in much of macroeconomics – is to adopt the rational expectations paradigm, whereby agents have perfect knowledge about the stochastic properties of the economy. While the rational expectations paradigm has several key advantages, such as analytical tractability, it rests on the strong presumption that individuals hold statistically correct (and thus unbiased) expectations about all future realizations of events.

Recent research has documented the expectations of households about labor market outcomes at the individual level. This includes, for example the expectations of workers about job loss, wage growth, or job finding; see Mueller and Spinnewijn (2023) for a survey. Contrary to the rational expectations hypothesis, this work provides mounting evidence for sizable and persistent biases in individual labor market expectations. For example, Mueller et al. (2021) use data from the Survey of Consumer Expectations to document that job seekers in the U.S. substantially over-estimate their job finding probability. Similar findings are obtained by Spinnewijn (2015) for the U.K. and by Balleer et al. (2022) for Germany. Along the same lines, Balleer et al. (2021) find that employed workers in the U.S. systematically under-estimate the probability of becoming unemployed, whereas Balleer et al. (2022) find the opposite for German workers who are stubbornly pessimistic about the stability of their job.[1]

The objective of this paper is twofold. First, we incorporate subjective expectations into a frictional labor market model in order to study the implications of biased expectations for wage bargaining, job creation and worker flows. Second, we analyze the effects of labor market policies on equilibrium outcomes in the presence of biased expectations. As a framework, we adopt the canonical search-and-matching model as described in Pissarides (2000) and used in many of the works described above. In a nutshell, in this framework firms need to be matched with a worker

[1] Several recent papers have studied the implications of the observed expectation biases for individuals' choices and aggregate outcomes. This includes, for example, job search effort and reservation wages (Mueller et al., 2021; Conlon et al., 2018), life-cycle consumption and aggregate wealth inequality (Balleer et al., 2021), the design of optimal unemployment insurance (Spinnewijn 2015), and the non-convergence of East-German labor market outcomes (Balleer et al., 2022).

in order to produce output. However, there are search frictions in the labor market. Firms post vacancies to attract workers and unemployed workers search for jobs. An aggregate matching function brings together vacant jobs and unemployed workers. Once matched, the worker and the firm negotiate the wage through bilateral Nash bargaining. The employment relation continues until the job is hit by an exogenous separation shock. When the match separates, the worker becomes unemployed and the firm's job becomes vacant.

In line with the evidence mentioned above, we allow workers in the model to have biased expectations about future realizations of individual labor market transitions. This includes the transition from unemployment to employment (job finding) and the transition back into unemployment (job separation). We define the bias in expectations as the difference between worker's subjective transition probabilities and the statistical probabilities. For example, an optimistic bias in the job finding expectation occurs when the worker over-estimates the probability of transiting from unemployment to employment. For tractability, we assume throughout the paper that the bias is the same across workers and constant over time.

We derive the equilibrium of the model and characterize analytically the effects of biases on the properties of the economy. Several key insights emerge from this analysis. Most importantly, in the presence of biased expectations the specific assumption about the frequency of wage bargaining becomes crucially important. When firms and workers renegotiate the wage **every period** – which is the approach predominately used in the literature – then a pessimistic bias in workers' separation expectations leads to a **higher** bargained wage. The intuition is that a pessimistic worker expects the employment relation to end soon, and thus, the firm has to offer a higher wage to make the worker stay in the match. However, importantly, this theoretical result is not supported by empirical evidence which instead points to a strongly negative relationship between a worker's wage and the individual separation expectation. For example, Balleer et al. (2022) use survey data for the U.S. and Germany and find statistically significant and strongly negative estimates for the elasticity of wages with respect to separation expectations.

In contrast, when firms and workers negotiate a multi-period wage contract which specifies the wage for the **duration of the match**, then the model's predictions are consistent with the empirical result that pessimistic workers earn **lower** wages. In the model, pessimistic workers accept low wages as they expect to receive the wage only for a short duration

In addition to these extreme cases (flexible wage and fixed wage) we also consider a bargaining setting where the wage is renegotiated after a predetermined number of periods. In this context, we isolate two opposing effects of the separation bias on the wage and we characterize a cutoff for the bargaining frequency below which the bias positively affects the worker's wage and above which the negative effect dominates. An immediate implication of this result is that, in the presence of biased expectations, the wage is crucially affected by how often workers and firms negotiate. This finding is in stark contrast to the rational expectations case where the frequency of bargaining is irrelevant for the level of wages.

To recap, our analysis reveals that the widely used assumption of period-by-period bargaining is generally problematic — when applied in the canonical search-and-matching model with subjective expectations – as it leads to counterfactual predictions of the model regarding the effect of bias on wages. Instead, a wage setting process with less frequent bargaining is found to be empirically consistent.

We consider several extensions of the baseline model. For example, we include risk averse workers. Risk aversion generally dampens the effect of expectation biases on wages and other equilibrium outcomes. The reason is that due to the declining marginal utility, risk averse workers have a lower (perceived) valuation of the bias than risk neutral workers. In another extension, we study the case where – in addition to workers – also firms have biased beliefs about labor market transitions (vacancy filling and job separation). We establish in this context is that only the amount of disagreement between the worker and the firm – but not the size of the respective expectation bias –matters for the wage bargaining. In other words, if the firm is equally pessimistic (or optimistic) than the worker, then the wage is the same as under rational expectations.

The remainder of the paper is structured as follows. In Section 2 we develop the theoretical framework and derive the main analytical results. In Section 3 we discuss the model extensions. In Sections 4 and 5 we explore the efficiency of equilibrium and analyze labor market policies. Section 6 concludes.

2 Search and matching with biased expectations

In this section, we explore the effects of biased labor market expectations on individual wages and aggregate outcomes within a random search-and-matching model of the labor market where wages are determined by (generalized) Nash bargaining between workers and firms.

2.1 Setup

Time is discrete. The economy is populated by a measure one of workers and a continuum of active firms. Workers are homogeneous, risk-neutral and infinitely lived, and they receive a period-wage ω when employed and income $b \geq 0$ when unemployed. Each active firm has one job that can be vacant or filled with a worker. A vacant job costs $\kappa > 0$ per period and a filled job produces output $z > 0$ per period, with $z > b$. Existing worker-firm pairs separate with exogenous per period probability $0 < \sigma \leq 1$.

Firms with vacant jobs and unemployed workers are randomly matched together. The matching function $M(u, v)$ determines the number of matches per period, where u is the number of unemployed workers and v is the number of vacant jobs. As is standard, we assume that $M(u, v)$ is homogeneous of degree 1, continuously differentiable, increasing and concave in v and u, and it satisfies $M(0,u) = M(v,0) = 0$, and $M(v,u) \leq \min(v,u)$.

We refer to the ratio of vacant jobs to unemployed workers as the labor market tightness and we denote it by $\theta \equiv v/u$. Moreover, we define the probability of an unemployment worker to match with a vacant job as $M(u,v)/u = M(1,\theta) \equiv m(\theta)$, and the probability of a vacancy to match with an unemployed worker as $M(u,v)/v = M(1,\theta)/\theta = m(\theta)/\theta$.

A common assumption in the literature is that firms and workers have rational expectations about the underlying matching and separation probabilities. These probabilities include for the worker the probability to find a job, $m(\theta)$, and the probability to transit from employment to unemployment, σ, whereas for the firm, this includes the probability to hire a worker $m(\theta)/\theta$ and the probability to separate from the worker σ. In line with the empirical evidence discussed in the Introduction, we depart from this assumption by allowing workers to have biased expectations about the transition probabilities. In our baseline analysis we assume that firms have the correct expectations but later we relax this assumption and also allow firms to have biased beliefs.

Concretely, we assume that workers expect to separate from a given job with per period probability $\sigma_w = (1 + \Delta_{\sigma w})\sigma$, and to find a job with probability $\lambda_w = (1 + \Delta_{\lambda w})m(\theta)$. $\Delta_{\sigma w}$ and $\Delta_{\lambda w}$ denote the bias in workers' expectations about job separation and job finding. Clearly, when $\Delta_{\cdot w} = 0$, there is no bias and workers have rational expectations. When $\Delta_{\sigma w} > 0$, then workers are pessimistic regarding the stability of their job as they expect to separate from their employer with a higher probability than the actual job separation probability. Conversely, when $\Delta_{\lambda w} > 0$, then workers have an optimistic bias in their job finding expectations as they expect to find a new job with a higher probability than the actual job finding probability. We assume that there is no heterogeneity among workers in the magnitude of the bias. That is, all workers are equally pessimistic, optimistic or rational. Moreover, we assume that the expectation biases are constant over time. In ongoing companion work, we relax these assumptions and study the case where workers differ in the magnitude of their bias and learn over time about the actual transition probabilities.

As is standard in this class of models, we assume that the wage ω is determined by generalized Nash bargaining between the firm and the worker. Importantly, we consider two versions of the bargaining process that differ in the number of periods that the wage is determined. First, we consider the case where the firm and the worker negotiate the wage **every period**. We refer to this case as the *Period-by-period bargaining* (PbP). In the second case, we assume that the firm and the worker negotiate a **multi-period** wage contract. In the baseline, we consider the extreme case where this contract specifies the wages for the entire employment spell. We refer to this case as the *Duration of match bargaining* (DM). In Section 3 we relax this assumption and allow that the wage is renegotiated after a finite number of periods.

PbP-bargaining is the common approach used in the literature and appreciated mainly for its tractability and analytical convenience. Versions of DM-bargaining are applied in the context of staggered wages to explain nominal wage rigidity. See Gertler and Trigari (2009) and the subsequent literature. The reason we consider these two bargaining settings is that they deliver drastically different predictions about how workers' expectation biases affect wages. In what follows, we analyze the stationary equilibrium of the model under each of the two bargaining settings.

2.2 Period-by-period bargaining

Value functions

As mentioned, we assume that firms and workers negotiate the wage in every period of the match. The value of a job for a worker is given by

$$E(\omega) = \omega + \beta(1-\sigma_w)E(\omega') + \beta\sigma_w U \tag{1}$$

where $0 < \beta < 1$ is the personal discount factor, $0 < \sigma_w < 1$ is the worker's subjective job loss expectation, ω' is the wage of next period, and U is the value of unemployment. The value of employment depends on the worker's current-period wage, ω, and the discounted continuation value. With (subjective) probability $(1-\sigma_w)$ the match continues and the worker obtains the value of employment also next period. With probability σ_w, the match is dissolved and the worker obtains the value of unemployment next period.

Importantly, E and U are the workers' perceived values of employment and unemployment. With biased expectations, E and U can differ from the actual values.

The value of unemployment for a jobless worker is given by

$$U = b + \beta\lambda_w E(\omega') + \beta(1-\lambda_w)U \tag{2}$$

where $b \geq 0$ is unemployment income and λ_w is the subjective job finding probability. Combining (1) and (2), we can express the surplus of a match for the worker as

$$E(\omega) - U = \omega - (1-\beta)U + \beta(1-\sigma_w)(E(\omega') - U)$$

Given this expression, we can define the worker's reservation wage, $\underline{\omega}$ in the standard way as the wage for which the worker is indifferent between working and unemployment, in which case the condition $E(\underline{\omega}) - U = 0$ is satisfied. It follows that

$$\underline{\omega} = (1-\beta)U - \beta(1-\sigma_w)(E(\omega') - U)$$

The worker's reservation wage has two terms: the per-period value of unemployment $(1-\beta)U$, and the worker's expected net surplus from continuing the match next period, $\beta(1-\sigma_w)(E(\omega') - U)$. The latter term raises the worker's value of forming a match today, and therefore it reduces the reservation wage. It is straightforward to see that the reservation wage increases in the pessimistic bias of the worker (for given values of E and U). This is intuitive as for higher values of σ_w the worker expects a lower duration of the current job and thus, the expected net surplus from continuing the match declines.

Next, we define the value of a match for the firm as

$$J(\omega) = z - \omega + \beta(1-\sigma)J(\omega') + \beta\sigma V \tag{3}$$

where $z > 0$ is output. The firm expects to separate from the worker with probability σ in which case it obtains the value of a vacant job denoted by V. V is defined as

$$V = -\kappa + \beta\lambda J(\omega') + \beta(1-\lambda)V \tag{4}$$

$\kappa > 0$ is the cost of an open vacancy and $\lambda = m(\theta)/\theta$ is the vacancy filling probability.

Combining (1)-(4) we can express the joint surplus of the match as

$$\begin{aligned} S(\omega) &= J(\omega) - V + E(\omega) - U \\ &= z - (1-\beta)(V+U) + \beta\Big[(1-\sigma)(J(\omega') - V) + (1-\sigma_w)(E(\omega') - U)\Big] \end{aligned}$$

Importantly, as in the case of rational expectations, the total match surplus is independent of the current wage, ω. This holds even if the worker has biased expectations about the duration of the match, $\sigma_w \neq \sigma$. In other words, the wage only divides the surplus between the firm and the worker. This will be different in the case of DM-bargaining, where ω determines the size of the joint surplus whenever $\sigma_w \neq \sigma$.

Wage bargaining

The wage ω is determined via generalized Nash bargaining between the firm and the worker. Concretely, the wage is set to maximize the Nash product:

$$\omega = \arg\max \Big[E(\omega) - U\Big]^{\gamma} \Big[J(\omega) - V\Big]^{1-\gamma} \tag{5}$$

where $0 \leq \gamma \leq 1$ is the worker's weight. The threat points in the bargain are the respective outside options which are the value of unemployment for the worker and the value of an open vacancy for the firm.

At this point, it is important to specify the information that is exchanged between the worker and the firm in the bargain. We assume that workers are not aware of their potential expectation bias. That is, they consider their subjective transition probabilities as the actual probabilities. Therefore, a worker with biased beliefs disagrees with the firm about the transition probabilities and, as a consequence, there is disagreement about the implied job values, $(J(\omega), E(\omega))$, and outside options, (V, U). In other words, the firm perceives a value of, say, $E(\omega)$ that is different from the worker's perceived value. In order to handle this discrepancy, we assume (i) that agents truthfully report their perceived values, (ii) that no persuasion takes place as an attempt to inform the counterpart, and (iii) that the firm accepts the values of $(E(\omega), U)$ as reported by the worker, and vice versa.

The optimality condition associated with the maximization problem in (5) is given by

$$\gamma\Big[J(\omega) - V\Big]\underbrace{\frac{\partial E(\omega)}{\partial \omega}}_{1} + (1-\gamma)\Big[E(\omega) - U\Big]\underbrace{\frac{\partial J(\omega)}{\partial \omega}}_{-1} = 0 \tag{6}$$

A marginal change in the wage has the same (absolute) effect on the worker's and the firm's value of the match. Specifically, a marginal decrease in ω decreases the worker's value $E(\omega)$ by the same amount that it increases the firm's value $J(\omega)$. Importantly, due to this property, the sharing of the joint match surplus between the worker and the firm is not affected by the worker's subjective separation expectation, σ_w. To see this, we substitute the definition of the joint surplus, $S(\omega)$ into the wage optimality condition to obtain the standard surplus sharing rule

$$\begin{aligned} (1-\gamma)\Big(E(\omega) - U\Big) = \gamma\Big(J(\omega) - V\Big) \quad &\Rightarrow \quad E(\omega) - U = \gamma S \\ &\Rightarrow \quad J(\omega) - V = (1-\gamma) S \end{aligned}$$

The wage is negotiated for the current period only, thus, it does not determine the future value of the job. As a consequence, the worker's expected duration of the match plays no role for how the surplus is split. (Again, this will be different in the case of DM-bargaining.) Similarly, the worker's job finding expectation, λ_w, also affects only the size of the total surplus – through its effect on the value of unemployment U – but not the split.

Partial equilibrium effects of expectation bias on the wage

While the bias has no effect on the sharing of the surplus, it nevertheless affects the bargained wage. In this section we illustrate this property in a partial equilibrium setting – where the value of market tightness, θ, is taken as given. The purpose of the analysis is to build intuition for how the worker's subjective beliefs shape the outcome of the bargaining process. These insights will be useful later to interpret the effects of the bias in general equilibrium.

As a starting point consider the case where $\Delta_{\sigma w} = \Delta_{\lambda w} = 0$. The solid lines in the upper panel of Figure 1 depict the left- and the right-hand side of the optimality condition (6) as a function of the wage (for the case $\gamma = 1/2$). These terms represent, respectively, the gain for the worker and the loss for the firm of a marginal increase in the wage:

$$\begin{aligned} E(\omega) - U &= \omega &&- (1-\beta)U &&+ \beta(1-\sigma_w)(E(\omega') - U) \\ J(\omega) - V &= z - \omega &&- (1-\beta)V &&+ \beta(1-\sigma)(J(\omega') - V) \end{aligned}$$

The slope of these functions is equal to +1 and −1, respectively.[2] The lower panel of the figure shows the Nash product. The optimality condition in (6) dictates that the Nash product reaches its maximum at the wage for which the worker's surplus $E(\omega)-U$ and the firm's surplus $J(\omega)-V$ intersect.

Next, consider worker with a pessimistic bias in the separation expectation. This case is represented by $\sigma_w > \sigma$. A pessimistic worker discounts more strongly the future value of the match. Thus, for any given wage, the worker's surplus is lower than before:[3]

$$E(\omega) - U = \omega - (1-\beta)U + \beta(1-\sigma_w)(E(\omega') - U) \quad \Rightarrow \frac{\partial E(\omega) - U}{\partial \sigma_w} < 0$$

In Figure 1, this case is represented by a downward-shift in the worker's surplus function (broken line). As a consequence, the implied reservation wage of the worker increases to $\overline{\omega}'$. In other words, the pessimistic worker would not agree to work for wages that the rational worker was willing to accept. As a result of the decline in $E(\omega) - U$, the joint match surplus $S = J(\omega) - V + E(\omega) - U$ is reduced for any level of the wage. This is shown in the lower panel of Figure 1 by the lower hump-shaped curved. Due to the downward-shift of the $E(\omega) - U$ line, the new point of intersection between the worker's and the firm's surplus function shifts to the right. Hence, the optimal wage is higher than before. In other words, the pessimistic worker is compensated by the firm for the loss in the surplus with a higher wage.[4] This is our first important result and we state it more formally below in Proposition 1.

In the next step, consider a worker with optimistic job finding expectations. When $\Delta_{\lambda w} > 0$, the worker overestimates the probability of finding employment. Thus, according to Equation (2), the value of unemployment, U, is perceived higher than without the optimistic bias, and hence, the surplus of employment, $E(\omega) - U$), is lower. This case is represented in the upper panel of Figure 1 by the broken line. As before, this shift leads to an increase in the reservation wage. Furthermore, a higher U means that the optimistic worker has a more valuable outside option in the bargain which leads to a higher wage.

Proposition 1 (Partial equilibrium wage effects under period-by-period bargaining)**.**
Under period-by-period bargaining and for any positive market tightness θ, the reservation wage $\underline{\omega}$ and the bargained wage ω are

i) increasing in the (optimistic) bias of worker's job finding expectation

$$\frac{\partial \underline{\omega}}{\partial \Delta_{\lambda w}} > 0, \qquad \frac{\partial \omega}{\partial \Delta_{\lambda w}} > 0$$

and

[2]The $\overline{w}$ in the figure represents the maximum wage that the firm is willing to pay. It is given by $J(\overline{\omega}) - V = 0 \Rightarrow \overline{\omega} = z - (1-\beta)V + \beta(1-\sigma_f)(J(\omega') - V)$.

[3]The derivative $\partial(E(\omega) - U)/\partial\sigma_w$ also captures the effect of σ_w on $E(\omega) - U$ via the implied change in U.

[4]Of course, the exact opposite holds in the case of an optimistic bias in the worker's separation expectation.

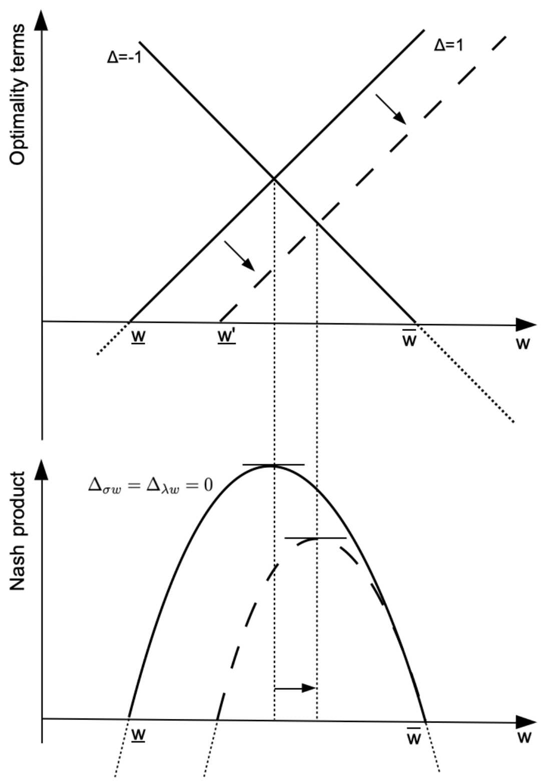


Figure 1: (PbP) Wage effects of bias, $\Delta_{\sigma w} > 0, \Delta_{\lambda w} > 0$

ii) increasing in the (pessimistic) bias of worker's separation expectation

$$\frac{\partial \underline{\omega}}{\partial \Delta_{\sigma w}} > 0, \qquad \frac{\partial \omega}{\partial \Delta_{\sigma w}} > 0.$$

General equilibrium

In the next step, we derive two conditions that jointly characterize the equilibrium of the model. The first condition represents the wage schedule that results from the bargaining process. To derive this schedule, we combine the optimality condition (6) with the value functions (1)-(4) and we use the fact that the value of an open vacancy, V, is equal to zero in equilibrium (due to free entry of firms). As a result, we obtain the following wage schedule:

$$\omega \;=\; b + \gamma \left[z - b + \kappa\theta \left(1 + \Delta_{\lambda w} + \sigma \frac{\Delta_{\sigma w}}{m(\theta)} \right) \right] \tag{7}$$

The structure of the wage schedule is very similar to that in the standard model with rational expectations. The equilibrium wage is given by the sum of unemployment income, b, and the worker's share, γ, of period match surplus; where the latter is equal to output net of forgone unemployment income, $z - b$, and the worker's compensation for helping the firm to save recruiting costs, $\kappa\theta(\cdot)$. It is straightforward to verify that in the absence of agents' expectation biases, the wage schedule in (7) is identical to the familiar rational expectations solution. To see this, set $\Delta_{\lambda w} = \Delta_{\sigma w} = 0$ to obtain $\omega = b + \gamma\,[z - b + \kappa\theta]$.

However, with biased beliefs the effects are as described before, with $\partial\omega/\partial\Delta_{\sigma w} > 0$ and $\partial\omega/\partial\Delta_{\lambda w} > 0$. Interestingly, while the job finding bias, $\Delta_{\lambda w}$, enters linearly, the effect of the separation bias, $\Delta_{\sigma w}$, is scaled with the value of the match for the firm. To see this, notice that in Equation (7), the term $\kappa\frac{1}{m(\theta)/\theta}$ represents the firm's expected hiring cost.[5] We will show below that the firm's surplus of the match is proportional to these costs. Thus, if the match is very valuable to the firm, then there is more value that can be transferred to the worker via a higher wage.

The wage curve in (7) establishes a relationship between the wage ω and the labor market tightness θ. Both variables are endogenous to the model and, hence, we require another condition to pin down their equilibrium values. To this end, we combine the firm's value functions (3) and (4) and use the fact that in a stationary equilibrium $V = 0$ and $J(\omega) = J(\omega')$. As a result, we obtain the so-called *job creation condition*

$$\frac{z-\omega}{1-\beta(1-\sigma)} = \frac{\kappa}{\beta m(\theta)/\theta} \tag{8}$$

The left-hand side of the expression represents the present discounted value of future period-profits, $z - \omega$, whereas the right-hand side represents the expected hiring costs. In equilibrium, expected profits and the expected costs are equalized so that all entering firms expect to make zero profits.

The equilibrium values of the wage and the labor market tightness are jointly determined by the wage curve in (7) and the job creation condition in (8). The job creation condition describes a negative relationship between ω and θ. The standard interpretation of this relationship applies: A high (low) wage implies low (high) period profits for the firm. To break even, the expected recruiting costs have to be low (high). A low (high) value of these costs is obtained when vacant jobs are filled quickly which happens when the market tightness, i.e. the ratio of open vacancies to job seekers, θ, is low (high). We show this more formally by applying the total differential to the wage schedule

$$\frac{\partial\omega}{\Delta\theta} = -(1-\epsilon_m)\frac{\kappa}{m(\theta)}\left(\frac{1}{\beta} - 1 + \sigma\right) < 0$$

where $\epsilon_m = \frac{\partial m(\theta)}{\partial\theta}\frac{\theta}{m(\theta)}$ is the elasticity of the matching probability with respect to labor market tightness. The matching function, $M(v,u)$, is homogenous of degree 1, hence, $m(\theta)$ is homogenous of degree less than 1 and it follows that $\epsilon_m < 1$.

For the wage curve, the relationship between wage and market tightness is less clear-cut. In the absence of expectation biases, we obtain the standard result that the wage increases in the tightness, $\frac{\Delta\omega}{\Delta\theta} = \gamma\kappa > 0$. The intuition is as follows. In a tight market (high θ) it is hard for the firm to fill a vacancy. Thus, the worker that stays with the firm helps to save substantial hiring

[5] κ is the vacancy cost per period and $\frac{1}{m(\theta)/\theta}$ is the expected duration of an open vacancy.

costs. The worker is compensated for these saved costs with a high wage. This can be different in a situation where the worker has biased expectations. To analyze this case we first rewrite the wage curve in Equation (7) to obtain

$$\omega = b + \gamma \left[z - b + \kappa\theta(1+\Delta_{\lambda w}) + \sigma_w \frac{\kappa}{m(\theta)/\theta} - \sigma \frac{\kappa}{m(\theta)/\theta} \right]$$

The term $\kappa\theta(1+\Delta_{\lambda w})$ reflects the hiring costs that the firm saves in the current period when the worker agrees to stay in the match. This term enters positively because a higher value of θ implies a higher value of costs that can be saved. An optimistic bias $\Delta_{\lambda w} > 0$ reinforces this effect as it implies that the worker overestimates the value of market tightness. The last two terms in the wage equation can be interpreted as follows. When a match exogenously separates, then the firm is left with an open vacancy and it has to incur recruiting costs to hire a new worker. The expected value of these costs is $\sigma \frac{\kappa}{m(\theta)/\theta}$; where σ is the separation probability and $\frac{\kappa}{m(\theta)/\theta}$ is the average hiring cost. An optimistic worker with $\sigma_w < \sigma$ underestimates the probability of a separation and thus perceives the expected hiring costs to be lower and equal to $\sigma_w \frac{\kappa}{m(\theta)/\theta}$. In the extreme case when $\sigma_w \to 0$, the worker beliefs the match to last forever, thus the perceived future recruiting costs are zero. Therefore, an increase in market tightness leads to an increase in the firm's future hiring costs, but since the optimistic worker underestimates this increase, the effect of a higher θ on the wage is negative. Thus, when the worker's optimism about match stability is sufficiently strong, then this negative effect dominates the positive effect. As a result, the wage declines with market tightness. More formally, we establish that:

$$\frac{\Delta\omega}{\Delta\theta} = \gamma\kappa \left(1 + \Delta_{\lambda w} + \frac{\sigma\Delta_{\sigma w}}{m(\theta)}(1-\epsilon_m)\right) \gtreqless 0 \qquad \Leftrightarrow \qquad \sigma - \sigma_w \lesseqgtr \frac{\lambda_w}{1-\epsilon_m} \tag{9}$$

To reiterate, Equation (9) shows that the wage increases (decreases) with tightness when the worker is sufficiently pessimistic (optimistic) about job separation and sufficiently optimistic (pessimistic) about job finding.

The equilibrium of the model is given by the pair (ω^*, θ^*) that jointly solves the wage curve (7) and the job creation condition (8). One can show that the existence and uniqueness of the equilibrium depends on the sign of the condition in (9). The following proposition makes this statement more formal.

Proposition 2 (Existence and uniqueness of equilibrium under period-by-period bargaining, with increasing wage curve)**.**
Under period-by-period bargaining, an equilibrium exists and is unique if the following two conditions are satisfied:

$$\sigma - \sigma_w \le \frac{(1+\Delta_{\lambda w})m(\theta)}{1-\epsilon_m} \qquad \textit{for all } \theta > 0$$

$$(1-\gamma)(z-b) > \kappa\left[\frac{1}{\beta} - (1-\sigma) - \gamma\sigma\Delta_{\sigma w}\right]$$

Figure 2 depicts the wage curve and the job creation condition, as well as the equilibrium that is characterized by Proposition 2. As we can see from the figure, the first condition in the proposition guarantees that the wage curve is non-decreasing for all values of θ, whereas the second condition guarantees that the intercept of the wage curve is located below the vertical intercept of the job creation condition for $\theta \to 0$.

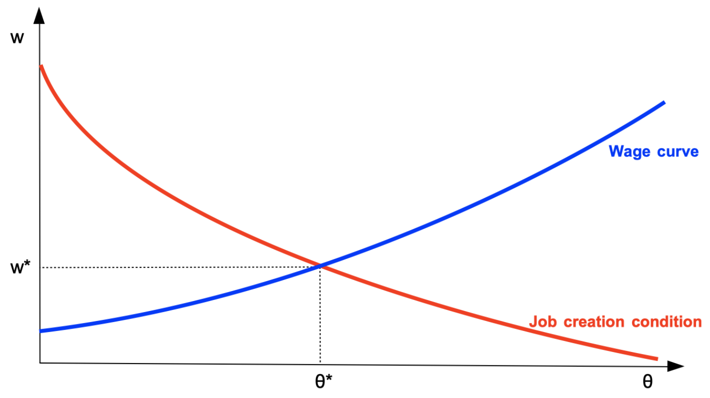
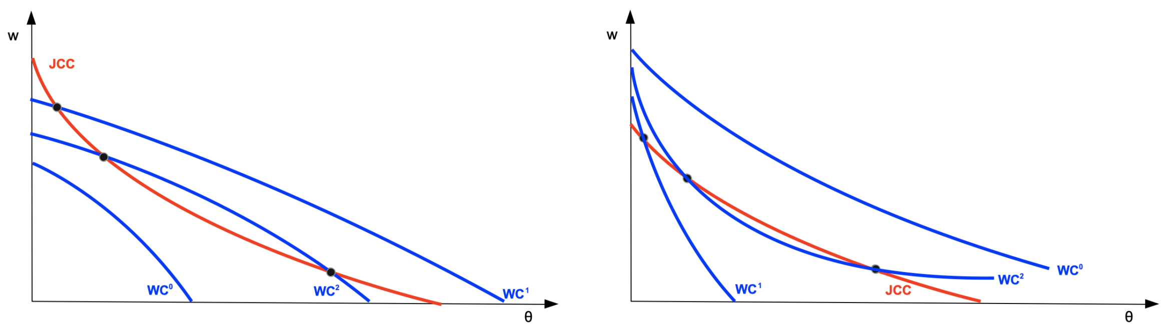


Figure 2: Equilibrium for $\frac{\Delta\omega}{\Delta\theta} \geq 0$

If the wage curve does not increases in market tightness, then – depending on the location of the wage curve – we may get no equilibrium, or one equilibrium, or multiple equilibria. Figure 3 illustrates some of these cases. The left (right) panel depicts the situation where the vertical intercept of the wage curve is below (above) the intercept of the job creation condition.



Panel(a): Intercept below **Panel(b): Intercept above**

Figure 3: Equilibrium for $\frac{\Delta\omega}{\Delta\theta} < 0$ (JCC: Job creation condition, WC: Wage curve)

The following proposition establishes necessary criteria for the existence of a unique equilibrium in the case of a decreasing wage curve.

Proposition 3 (Existence and uniqueness of equilibrium under period-by-period bargaining, with decreasing wage curve)**.**
Under period-by-period bargaining, an equilibrium exists and is unique if the conditions in (Ia.)-

(Ib.) or in (IIa.)-(IIb.) are jointly satisfied:

$$
\begin{aligned}
&(Ia.) && \sigma - \sigma_w < \kappa(1 + \Delta_{\lambda w})\tfrac{m(\theta)}{1-\epsilon_m(\theta)} + \kappa\tfrac{1-\beta(1-\sigma)}{\gamma\beta} && \textit{for all } \theta > 0 \\
&(Ib.) && (1-\gamma)(z-b) > \kappa\left[1/\beta - (1-\sigma) - \gamma\sigma\Delta_{\sigma w}\right] &&
\end{aligned}
$$

$$
\begin{aligned}
&(IIa.) && \sigma - \sigma_w > \kappa(1 + \Delta_{\lambda w})\tfrac{m(\theta)}{1-\epsilon_m(\theta)} + \kappa\tfrac{1-\beta(1-\sigma)}{\gamma\beta} && \textit{for all } \theta > 0 \\
&(IIb.) && (1-\gamma)(z-b) < \kappa\left[1/\beta - (1-\sigma) - \gamma\sigma\Delta_{\sigma w}\right] &&
\end{aligned}
$$

As we can see from Panel (a) in Figure 3, the condition (Ia.) in Proposition 3 guarantees that the wage curve declines less in θ than the job-creation curve, whereas (Ib.) guarantees that the intercept of the wage curve is located below the vertical intercept of the job creation condition for $\theta \to 0$. Similarly, the conditions (IIa.) and (IIb.) ensure that the wage curve labelled "WC^1" in Panel (b) of the figure has a higher intercept than the job creation condition but then declines more strongly in market tightness.

Lastly, we perform a comparative statics exercise to analyze the effects of biases on the equilibrium. For this exercise, we consider the equilibrium described in Proposition 2 and as a reference point we take the situation where agents have rational expectations.

An optimistic bias in the job finding probability $\Delta_{\lambda w} > 0$ leads to an upward-shift of the wage curve as workers expect to find jobs more easily. As a consequence, the firm pays a higher wage to compensate the worker for staying in the match. The higher wage implies that firms require lower expected recruiting costs to break even. This is achieved by a lower vacancy duration for which the market tightness has to decline. Due to the lower θ the equilibrium unemployment rate $u = \frac{\sigma}{\sigma + m(\theta)}$ and the unemployment duration $d = 1/m(\theta)$ increase. A pessimistic bias in the worker's separation expectation $\Delta_{\sigma w} > 0$ leads to an upward-shift in the wage curve. As the worker expects to loose the job soon, the firm has to offer a higher wage to make worker stay. The higher wage leads to same adjustment of tightness as in the previous case. These results are succinctly presented in the following proposition

Proposition 4 (General equilibrium effects under period-by-period bargaining)**.**
If wages are determined using period-by-period bargaining, and under the assumptions of Proposition 2, the equilibrium market tightness θ, wage, unemployment rate, and unemployment duration are

i) increasing in the (optimistic) bias of worker's job finding expectation

$$\frac{\partial \theta}{\partial \Delta_{\lambda w}} > 0, \quad \frac{\partial \omega}{\partial \Delta_{\lambda w}} > 0, \quad \frac{\partial u}{\partial \Delta_{\lambda w}} > 0, \quad \frac{\partial d}{\partial \Delta_{\lambda w}} > 0$$

and

ii) increasing in the (pessimistic) bias of worker's separation expectation

$$\frac{\partial \theta}{\partial \Delta_{\sigma w}} > 0, \quad \frac{\partial \omega}{\partial \Delta_{\sigma w}} > 0, \quad \frac{\partial u}{\partial \Delta_{\sigma w}} > 0, \quad \frac{\partial d}{\partial \Delta_{\sigma w}} > 0.$$

2.3 Duration of match bargaining

In the next step, we analyze the case where the worker and the firm negotiate a multi-period wage contract. As mentioned previously, we consider the extreme case where this contract specifies the wage payment for every period of the entire employment spell. We consider a stationary environment where z is constant over time, hence, this bargaining setting amounts to a situation where, upon matching, the worker and the firm negotiate a single wage schedule that applies in every period of the match. Many parts of the model are similar to before and thus, we keep the exposition brief. The value of a match for the worker is given by:

$$E(\omega) = \omega + \beta(1 - \sigma_w)E(\omega) + \beta\sigma_w U \tag{10}$$

In contrast to the case with PbP-bargaining, the current wage ω now applies also to the next period. The value of unemployment is the same as before and given by

$$U = b + \beta\lambda_w E(\omega) + \beta(1 - \lambda_w)U \tag{11}$$

We combine (10) and (11) to express the surplus of employment for the worker

$$E(\omega) - U = \frac{\omega - (1 - \beta)U}{1 - \beta(1 - \sigma_w)} \tag{12}$$

From that we can express the reservation wage, $\underline{\omega}$, as

$$E(\underline{\omega}) - U = 0 \qquad \Rightarrow \qquad \underline{\omega} = (1 - \beta)U$$

Two aspects about the reservation wage are different than before. First, it consists only of the per-period value of unemployment $(1 - \beta)U$, whereas before it also depended on the continuation value of the job. In other words, whether the worker is indifferent between employment and unemployment depends only on the per-period difference $\omega - (1 - \beta)U$, but not on the expected duration of the match. Therefore, the worker's separation expectation, σ_w, has **no** direct effect on the reservation wage.

The value of a match for the firm is given by

$$J(\omega) = z - \omega + \beta(1 - \sigma)J(\omega) + \beta\sigma V \tag{13}$$

and the value of a vacancy is

$$V = -\kappa + \beta\lambda J(\omega) + \beta(1 - \lambda)V \tag{14}$$

We combine the value functions in (10)-(14) to express the joint surplus of the match:

$$S(\omega) = J(\omega) - V + E(\omega) - U = \frac{z - \omega - (1-\beta)V}{1 - \beta(1-\sigma)} + \frac{\omega - (1-\beta)U}{1 - \beta(1-\sigma_w)} \tag{15}$$

Importantly, under DM-bargaining, the wage not only determines the share of the joint surplus that goes to the firm and the worker but also the level of $S(\omega)$. This is different under PbP-bargaining, where the joint surplus is independent of the wage. As we can see from Equation (15), the wage determines the size of $S(\omega)$ whenever the worker has biased separation expectations. For example, when the worker is pessimistic, $\sigma_w > \sigma$, then

$$\frac{\partial S(\omega)}{\partial \omega} = \frac{\partial J(\omega)}{\partial \omega} + \frac{\partial E(\omega)}{\partial \omega} = -\frac{1}{1-\beta(1-\sigma)} + \frac{1}{1-\beta(1-\sigma_w)} < 0$$

To understand this relationship, it is important to notice that a marginal change in the wage has a differential impact on the worker's and the firm's surplus. More specifically, when $\sigma_w > \sigma$, then a marginal increase in the wage ω increases the worker's surplus $E(\omega)$ by less (in absolute value) than it decreases the firm's surplus $J(\omega)$. This is because the separation probability determines the expected duration for which the wage is paid. Thus, if the worker expects a shorter duration than the firm, then the perceived gain for the worker from a higher wage is smaller than the loss for the firm.

Wage bargaining

As before, the wage ω is set to maximize the Nash product

$$\omega = \arg\max \Big[E(\omega) - U\Big]^{\gamma} \Big[J(\omega) - V\Big]^{1-\gamma}$$

The optimality condition associated with this problem is given by

$$\gamma\Big[J(\omega) - V\Big] \underbrace{\frac{\partial E(\omega)}{\partial \omega}}_{\frac{1}{1-\beta(1-\sigma_w)}} + (1-\gamma)\Big[E(\omega) - U\Big] \underbrace{\frac{\partial J(\omega)}{\partial \omega}}_{-\frac{1}{1-\beta(1-\sigma)}} = 0$$

This condition differs in two respects from that obtained under PbP-bargaining. First, the derivative of the worker's and the firm's value function with respect to the wage are larger than unity (in absolute value). This is because a marginal change in ω affects not only the instantaneous value of the match (as under PbP-bargaining) but also the future values. Second, as mentioned before, when $\sigma_w \neq \sigma$, then a marginal change in the wage affects the worker's value differently than the firm's value. Thus, we have that

$$\left|\frac{\partial E(\omega)}{\partial \omega}\right| \neq \left|\frac{\partial J(\omega)}{\partial \omega}\right|$$

We can write the optimality condition as

$$(1-\gamma)\Big(E(\omega)-U\Big) = \frac{1-\beta(1-\sigma)}{1-\beta(1-\sigma_w)}\gamma\Big(J(\omega)-V\Big) \tag{16}$$

from which we derive the worker's share in the total surplus

$$\frac{E(\omega)-U}{S(\omega)} = \gamma\left[\frac{1}{\gamma+(1-\gamma)\frac{1-\beta(1-\sigma_w)}{1-\beta(1-\sigma)}}\right]$$

As already alluded to, the sharing of the total surplus between the firm and the worker depends on the agents' subjective separation probability. As we can see from the previous expression, the worker's share in the surplus is equal to γ when $\sigma_w = \sigma$. However, it is less than γ when the worker is pessimistic about the match duration, and it is larger than γ when the worker is optimistic. The intuition for this relationship will be discussed in the next section.

Partial equilibrium effect of expectation bias on the wage

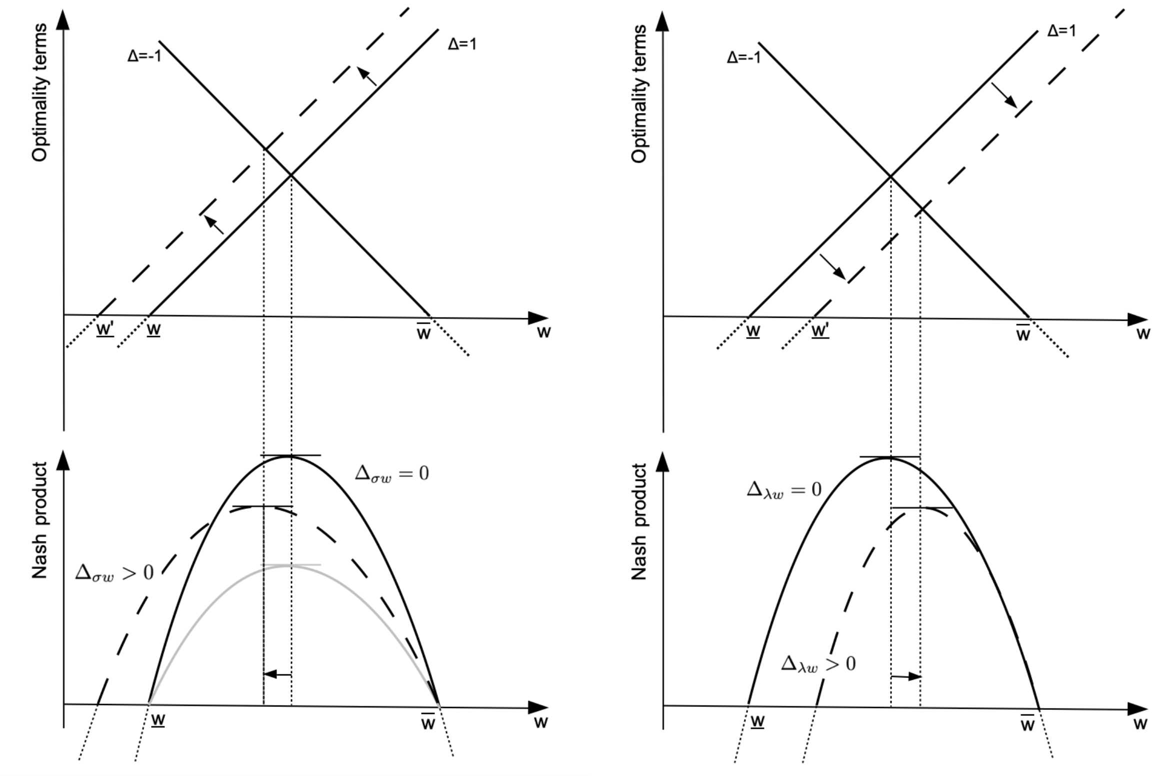
In the next step, we study as before – in partial equilibrium – how workers expectation bias affects the bargained wage. We consider the case of no bias as a reference point. For the interpretation, it will be useful to rewrite the wage optimality condition (16) by using the value function in (10)-(14) to substitute for the worker's and the firm's surplus. This yields the following expression

$$\begin{aligned} (1-\gamma)\Big(E(\omega)-U\Big)\Big(1-\beta(1-\sigma_w)\Big) &= \gamma\Big(J(\omega)-V\Big)\Big(1-\beta(1-\sigma_f)\Big) \\ \Rightarrow \qquad (1-\gamma)\Big(\omega-(1-\beta)U\Big) &= \gamma\Big(z-\omega-(1-\beta)V\Big) \end{aligned}$$

The solid lines in the upper panels of Figure 4 depict both sides of the wage optimality condition (for $\gamma = 0.5$). As we can see from the previous expression, both sides of the optimality condition have a slope of one (in absolute value). As a result, the Nash product – depicted in the lower panels of the figure – reaches its maximum at the level of the wage for which the two lines intersect.

Now, consider a worker with pessimistic separation expectations $\sigma_w > \sigma$. As we can see from Equation (12), a higher value of σ_w implies that the worker discounts future wages more heavily which leads to a decline in the worker's match surplus. However, as mentioned before, the reservation wage is unaffected by changes in the the worker's separation expectation. The decline in the worker's surplus reduces the value of the Nash product for any wage within the bargaining set $(\underline{\omega}, \overline{w})$. This is represented by the grey line in the lower part of Panel (a) in Figure 4. While the Nash product is lower than before, its maximum is attained for the same wage. To see this, consider the wage optimality condition from above. It implies that for a given value of U, the optimal wage is unaffected by the worker's separation expectation.

However, clearly, the value of unemployment, U, is different for a pessimistic worker. In particular, a higher σ_w implies a lower U since the pessimistic worker considers future employment less



(a.) Pessimistic job separation, $\Delta_{\sigma w} > 0$ **(b.) Optimistic job finding, $\Delta_{\lambda w} > 0$**

Figure 4: (DM) Wage effects of bias

attractive. As a result, the surplus of the current match rises. This situation is represented in the upper part of Panel (a) by an upward shift in the line representing the term $(\omega - (1-\beta)U)$, and a decline in the worker's reservation wage. Due to the decline in the worker's outside option, U, the new maximum of the Nash product is attained for a lower wage ω. Intuitively, the lower wage is optimal because the pessimistic worker discounts the future more than the firm and thus, the lower wage decreases the worker's value of employment by less than it increases the value of the match for the firm. We state this result more formally below in Proposition 5. Notice that this finding is the exact opposite of what we obtained under PbP-bargaining. In Section 2.4 we discuss in detail why the two bargaining settings deliver such opposing results regarding the wage effect of the separation bias.

As before under PbP-bargaining, an optimistic bias in the worker's job finding expectation increases the value of unemployment and thus, leads to a higher reservation wage. This situation is depicted in Panel (b) of Figure 4. With a more valuable outside option, the worker ends up with a better bargain and obtains a higher wage.

Proposition 5 (Partial equilibrium wage effects under duration-of-match bargaining)**.**
If wages are determined using duration-of-match bargaining, for any positive market tightness θ, the reservation wage $\underline{\omega}$ and the bargained wage ω are

i) increasing in the (optimistic) bias of worker's job finding expectation

$$\frac{\partial \underline{\omega}}{\partial \Delta_{\lambda w}} > 0, \qquad \frac{\partial \omega}{\partial \Delta_{\lambda w}} > 0$$

and

ii) decreasing in the (pessimistic) bias of worker's separation expectation

$$\frac{\partial \underline{\omega}}{\partial \Delta_{\sigma w}} < 0, \qquad \frac{\partial \omega}{\partial \Delta_{\sigma w}} < 0.$$

General equilibrium

In the next step, we analyze the equilibrium of the model. For this purpose, we derive the wage curve and the job creation condition. We obtain the wage curve by combining the optimality condition (16) with the agents' value functions (10)-(14) and we use the fact that $V = 0$ in equilibrium. As a result, we obtain:

$$\omega = b + \gamma \Big[z - b + \frac{1-\beta(1-\sigma)}{1-\beta(1-\sigma_w)} \kappa\theta \left(1 + \Delta_{\lambda w}\right) \Big] \tag{17}$$

As before under PbP-bargaining, the wage is equal to the sum of unemployment income, b, and the worker's share γ in the per-period match surplus. Also, it is straightforward to verify that in the absence of expectation biases, the wage curve is equal to the rational expectations solution.

With biased beliefs, the effects of the bias on the wage are as described before with $\partial\omega/\partial\Delta_{\sigma w} < 0$ and $\partial\omega/\partial\Delta_{\lambda w} > 0$. Moreover, the specific bargaining setting does not affect the value functions of the firm and the free entry condition. Thus, the job creation condition under DM-bargaining is identical to that under PbP-bargaining and given by Equation (8).

As before, the equilibrium of the model is described by the pair (ω^*, θ^*) that jointly solves the job creation condition and the wage curve. As we can see from Equation (17), the wage curve describes a positive relationship between the wage and labor market tightness. This relationship holds for any value of σ_w. Thus, unlike in the case of PbP-bargaining, the existence and uniqueness of equilibrium under DM-bargaining is independent of the workers' subjective separation probabilities. Concretely, we can state the following proposition.

Proposition 6 (Existence and uniqueness of equilibrium under duration-of-match bargaining)**.** *Under duration-of-match bargaining, an equilibrium exists and is unique iff the job-creation curve lies above the wage curve for $\theta \to 0$. This is the case, when the following condition is satisfied:*

$$(1-\gamma)(z-b) > \kappa \left[\frac{1}{\beta} - (1-\sigma) \right]$$

In the last step, we perform comparative statics to investigate how workers' expectation biases affect equilibrium outcomes. We focus only the separation expectations, because the matching expectations have the same effects as in the case of PbP-bargaining. As before, we use rational expectations as the reference point. A pessimistic bias in the worker's separation expectation $\Delta_{\sigma w} > 0$ leads to a downward-shift in the wage curve. The pessimistic worker expects a shorter duration of the match and, thus, perceives a lower value of saved recruiting costs. The firm compensates the worker for these costs by paying a lower wage. As the job creation condition is unaffected by the worker's separation expectation, the shift in the wage curve leads to an increase in the equilibrium labor market tightness. Lower wages imply higher firms' profits which encourages vacancy creation and leads to a higher value of θ.

Proposition 7 (General equilibrium effects under duration-of-match bargaining)**.**
If wages are determined using duration-of-match bargaining, and under the assumption of Proposition 6, the equilibrium market tightness θ, wage, unemployment rate, and unemployment duration are

i) increasing in the (optimistic) bias of worker's job finding expectation

$$\frac{\partial \theta}{\partial \Delta_{\lambda w}} > 0, \quad \frac{\partial \omega}{\partial \Delta_{\lambda w}} > 0, \quad \frac{\partial u}{\partial \Delta_{\lambda w}} > 0, \quad \frac{\partial d}{\partial \Delta_{\lambda w}} > 0$$

and

ii) increasing in the (pessimistic) bias of worker's separation expectation

$$\frac{\partial \theta}{\partial \Delta_{\sigma w}} < 0, \quad \frac{\partial \omega}{\partial \Delta_{\sigma w}} < 0, \quad \frac{\partial u}{\partial \Delta_{\sigma w}} < 0, \quad \frac{\partial d}{\partial \Delta_{\sigma w}} < 0.$$

2.4 Discussion

The purpose of this section is to briefly discuss why the two bargaining settings considered above lead to such different effects of the job separation bias on the wage. To reiterate, we established that a pessimistic bias leads to a higher wage (than under rational expectations) in the case when wages are renegotiated every period. In contrast, when the worker and the firm set the wage for the entire duration of the match, then the bias leads to a lower wage.

The starting point of our consideration is the case of a worker with unbiased expectations who earns a given wage ω. Suppose that this worker becomes pessimistic, with $\Delta_{\sigma w} > 0$. For the same wage ω, the perceived match surplus, $E(\omega) - U$, is lower than before because the pessimistic worker expects a lower duration of the match. This logic holds irrespective of the bargaining setting. A first important difference between the two bargaining settings emerges since with PbP-bargaining, the pessimistic worker's reservation wage is higher than before while it is lower with DM-bargaining. The underlying reason can be observed in Equation (18) which shows the reservation wage $\underline{\omega}$ for the two bargaining settings. Notice that the value of unemployment U declines with the bias – because the pessimistic worker considers future employment less valuable – which negatively affects the reservation wage in both cases. However, under PbP-bargaining this effect is dominated by the additional positive effect which is due to the decline in the (subjective) discounted value of future employment $\beta(1-\sigma_w)\Big(E(\omega')-U\Big)$.

$$\begin{aligned} &\textbf{Period-by-period} \qquad \underline{\omega} = (1-\beta)U - \beta(1-\sigma_w)\Big(E(\omega')-U\Big) \\ &\textbf{Duration-of-match} \qquad \underline{\omega} = (1-\beta)U \end{aligned} \tag{18}$$

Under PbP-bargaining, it is optimal for the firm to compensate the worker in the bargain and to pay a higher wage to raise the worker's perceived match surplus $E(\omega)-U$. It is optimal in the sense that it raises the Nash product. This is because, under PbP-bargaining, the wage is set for just one period and hence it does not affect the future surplus of the match. Consequently, the worker's biased discounting of the future (represented by $\beta(1-\sigma_w)$) does not matter for the effect of the current-period wage ω on the worker' perceived match surplus $E(\omega)-U$. As a result, the increase in the wage raises the workers surplus by the same amount (in absolute value) than it decreases the firm's surplus. In the end, the worker obtains the same share, γ, of the total match surplus $S(\omega)$, as before with unbiased expectations.

The situation is very different with DM-bargaining. In this setting, the wage is set for all periods and, thus, it affects the future surplus of the match. As a result, and in contrast to PbP-bargaining, the worker's subjective discount factor now plays a key role. Since the pessimistic worker strongly discounts the future effects of the wage on the match surplus, it is optimal for the firm to set a lower wage. The reason is that due to the biased discounting, the reduction in worker's perceived match surplus due to the lower wage is less (in absolute value) than the gain in the firm's surplus. As a result, the pessimistic worker can extract a share of the total match surplus of less than γ.

3 Extensions

3.1 Period-T renegotiation

Clearly, the bargaining settings considered in Sections 2.2 and 2.3 are two extreme cases. Wages are hardly set in stone for the entire employment spell nor are they renegotiated every period. A more realistic scenario is an intermediate setting where the worker and the firm renegotiate the wage after a certain number of periods. In this section, we consider this case. The analysis of such a setting is of interest per se but, moreover, it will be useful to bring the findings of the previous sections into context. Of particular interest is the question to what extent the bargaining horizon, i.e. the number of periods for which the wage is fixed, matters for how the worker' separation bias affects the wage.

Specifically, consider the framework from Section 2 and suppose that the worker and the firm bargain over the wage every T periods. Once the wage is set, it stays fixed until the next bargaining round. The worker's match surplus can be derived from the value function in (1) and it is given by

$$E_T(\omega) - U = \underbrace{[\omega - (1-\beta)U] \sum_{t=1}^{T} (\beta(1-\sigma_w))^{t-1}}_{\text{Period surplus}} + \underbrace{[\beta(1-\sigma_w)]^T \Big(E_T(\omega') - U\Big)}_{\text{Continuation value}} \tag{19}$$

The worker obtains a given wage ω for a total of T periods. Thus, the first term in the expression represents the discounted sum of period surplus, $\omega - (1-\beta)U$, that accrues from these wage payments. After T periods, the worker and the firm negotiate again. Thus, the second term reflects the discounted continuation value of the match that the worker obtains given the new wage ω'.

It is straightforward to see that this specification nests the two bargaining settings from above. When $T = 1$ the worker obtains the period surplus only once. Instead when $T \to \infty$, then the continuation value vanishes – since $\lim_{T\to\infty} [\beta(1-\sigma_w)]^T = 0$.

$$\begin{aligned} &\text{PbP} \qquad T = 1 \qquad E_1(\omega) - U = \omega - (1-\beta)U + \beta(1-\sigma_w)\Big(E(\omega') - U\Big) \\ &\text{DM} \qquad T \to \infty \qquad E_\infty(\omega) - U = \frac{\omega - (1-\beta)U}{1 - \beta(1-\sigma_w)} \end{aligned}$$

Using the worker's surplus in Equation (19) and the firm's surplus we solve the Nash bargaining problem and obtain the following wage schedule.[6]

$$\omega_T = b + \gamma \left[z - b + \kappa\theta \left(\overbrace{\frac{\sum_{t=1}^{T} \Big(\beta(1-\sigma_w)\Big)^{t-1}}{\sum_{t=1}^{T} \Big(\beta(1-\sigma)\Big)^{t-1}}}^{\frac{\partial \cdot}{\partial \sigma_w} < 0} (1 + \Delta_{\lambda w}) + \overbrace{\beta^{T-1} \frac{(1-\sigma)^T - (1-\sigma_w)^T}{m(\theta) \sum_{t=1}^{T} \Big(\beta(1-\sigma)\Big)^{t-1}}}^{\frac{\partial \cdot}{\partial \sigma_w} > 0} \right) \right] \tag{20}$$

This expression is a convex combination of the wage schedules obtained for the PbP- and the DM-bargaining setting; it is straightforward to verify that for $T = 1$ ($T \to \infty$) it boils down to the PbP- (DM-)solution. Next, we use the wage curve to show how the bargaining frequency T matters for the effect of the worker's separation bias on the wage. In this context, it is useful to recall the findings from above: With PbP-bargaining we obtain a positive effect of the bias on the wage, whereas with DM-bargaining the effect was negative.

In the general bargaining setting considered here, the effect of the separation bias on the wage depends on two opposing effects. These two effects are represented in Equation (20) by the two terms inside the round brackets. The first term depends negatively on the bias. The underlying

[6]The derivations are in the Appendix.

intuition is as discussed in the context of the DM-bargaining. To reiterate, a pessimistic worker discounts future wages more strongly than the firm and therefore agrees to a lower wage. In contrast, the second term in brackets depends positively on the bias. The intuition is as in the case of PbP-bargaining: A pessimistic worker strongly discounts the (future) surplus of the match that is obtained in the next bargaining round. The firm compensates the worker for the lower perceived job value by paying a higher wage.

As we can see from Equation (20), the bargaining horizon affects the strength of these two effects. When $T = 1$, then the wage is fixed for just one period. Therefore, the difference in the effective discount factor between the worker $\beta(1 - \sigma_w)$ and the firm $\beta(1 - \sigma)$ is irrelevant. More specifically, when $T = 1$, then a higher wage raises the worker's surplus by the same absolute value that it lowers the firm's surplus. This relationship is illustrated in Panel (a) of Figure 5 where $\frac{\partial E(\omega) - U}{\partial \omega} = \left| \frac{\partial J(\omega) - V}{\partial \omega} \right| = 1$ for $T = 1$. As a result, the first (negative) effect is not present and we obtain that $\frac{\partial \omega_T}{\partial \sigma_w} > 0$. However, for $T > 1$ the first effect comes into play and it becomes more important as the bargaining horizon increases. The reason is that, for $T > 1$, the differential discounting between the firm and the worker starts to matter. This implies that in the case of a pessimistic worker, a higher wage raises the worker's surplus by less than it lowers the firm's surplus. More formally:

$$\frac{\partial E(\omega) - U}{\partial \omega} = \sum_{t=1}^{T} \Big(\beta(1 - \sigma_w)\Big)^{t-1} < \sum_{t=1}^{T} \Big(\beta(1 - \sigma)\Big)^{t-1} = \left| \frac{\partial J(\omega) - V}{\partial \omega} \right| \qquad \text{for } T > 1 \tag{21}$$

This relationship is illustrated in Panel (a) of Figure 5 where $\frac{\partial E(\omega) - U}{\partial \omega} < \left| \frac{\partial J(\omega) - V}{\partial \omega} \right|$ for $T > 1$. The maximum difference in the discounting is obtained for the longest possible bargaining horizon, i.e. for $T \to \infty$. In this case – which is the DM-bargaining setting – the separation bias has the largest negative effect on the wage.

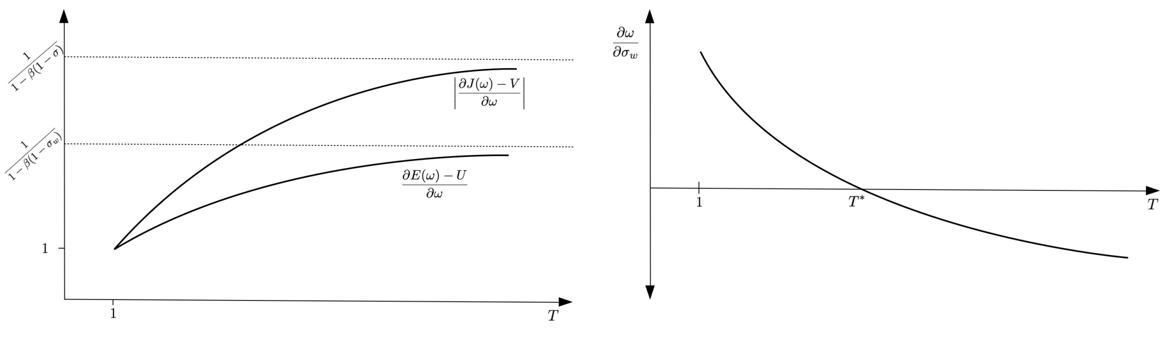


Figure 5

At the same time, as T increases, the next bargaining round moves further and further into the distant future. Therefore, the worker discounts more strongly the surplus which is associated with the next round, $E(\omega') - U$. As a result, a pessimistic worker requires less and less compensation for the decline in future surplus. Thus, the second (positive) effect of the separation bias on the wage becomes less important as the bargaining horizon increases.

To summarize, as the bargaining horizon increases, the negative effect of the separation bias on the wage becomes larger and the positive effect becomes smaller. This implies that the derivative $\frac{\partial \omega}{\partial \sigma_w}$ is monotonically decreasing in T, as shown in Panel (b) of Figure 5. Together with a positive derivative for $T = 1$ and a negative derivative for $T \to \infty$, there exists a unique cutoff for the bargaining frequency T^* such that the wage increases with the bias for all $T < T^*$ and the wage decreases with the bias for all $T \geq T^*$. In the Appendix we show that this unique cutoff is given by the smallest integer which satisfies the following condition:

$$\frac{\partial \omega_T}{\partial \sigma_w} < 0 \qquad \iff \qquad \frac{T^*}{(1+\Delta_{\lambda w})m(\theta)} < \beta \sum_{t=1}^{T^*-1} (T^* - t)\Big(\beta(1-\sigma_w)\Big)^{-t}$$

Lastly, it is important to notice that the job creation condition is not affected by the length of the bargaining horizon. Thus, the expression in Equation (8) also applies to the case of period-T bargaining.

3.2 Bias in workers' and firms' expectations

As another extension, we also allow firms to have biased expectations about job separation and vacancy filling. Concretely, we assume that firms expect to separate from a worker with probability $\sigma_f = (1+\Delta_{\sigma f})\sigma$, and to meet an unemployed worker with probability $\lambda_f = (1+\Delta_{\lambda f})m(\theta)/\theta$. Thus, $\Delta_{\sigma f}$ and $\Delta_{\lambda f}$ denote the bias in firms' expectations about match separation and vacancy filling.

In order to analyze the equilibrium of this extended model, we derive the job creation condition and the wage curve – see the Appendix for the calculations. As in the previous section, we assume that wages are renegotiated after T periods. The job creation condition is given by the following expression:

$$\frac{z - \omega}{1 - \beta(1-\sigma_f)} = \frac{\kappa}{\beta(1+\Delta_{\lambda f})m(\theta)/\theta} \tag{22}$$

As before, the left-hand side of the expression represents the present discounted value of future period-profits, $z - \omega$, whereas the right-hand side represents the expected hiring costs. A bias in firm's subjective matching and separation probabilities affects the perceived costs and profits, and thereby the bias shapes firm entry and vacancy creation. For example, a pessimistic bias in the separation probability, $\Delta_{\sigma f} > 0$ lowers the left-hand side of Equation (22) because a pessimistic firm expects to reap the period-profits $z - \omega$ for a shorter duration. For a given wage, ω, this leads to fewer vacancy creation and a drop in the labor market tightness, θ. Similarly, a pessimistic bias in the matching probability, $\Delta_{\lambda f} < 0$ increases the right-hand side of Equation (22) as the firm expects higher recruiting costs to find a worker. Again, for a given wage, this leads to a fewer vacancies in equilibrium.

We obtain the following expression for the wage schedule

$$\omega_T = b+\gamma\left[z-b+\kappa\theta\left(\frac{\sum_{t=1}^{T}\Big(\beta(1-\sigma_w)\Big)^{t-1}}{\sum_{t=1}^{T}\Big(\beta(1-\sigma_f)\Big)^{t-1}}\left(\frac{1+\Delta_{\lambda w}}{1+\Delta_{\lambda f}}\right)+\beta^{T-1}\frac{(1-\sigma_f)^T-(1-\sigma_w)^T}{(1+\Delta_{\lambda f})m(\theta)\sum_{t=1}^{T}\Big(\beta(1-\sigma_f)\Big)^{t-1}}\right)\right] \tag{23}$$

The wage schedule reveals the interesting implication that only the amount of disagreement between the worker and the firm – but not the size of their expectation bias –matters for the wage. In other words, if the firm is equally pessimistic (or optimistic) than the worker, ($\Delta_{\sigma w} = \Delta_{\sigma f}$ and $\Delta_{\lambda w} = \Delta_{\lambda f}$), then the wage curve is the same as under rational expectations.[7] The reason for this "equivalence result" is twofold. First, the perceived value of (saved) recruiting costs depends on the ratio of worker's subjective job finding probability to the firm's subjective vacancy filling probability. This ratio is equivalent to the agents' perceived labor market tightness, $\theta\left(\frac{1+\Delta_{\lambda w}}{1+\Delta_{\lambda f}}\right)$. If agents' agree on the value of tightness, then they perceive the same value of recruiting costs. Second, when $\Delta_{\sigma w} = \Delta_{\sigma f}$, then the worker and the firm agree on the expected duration of the match. In this case, agents share the same discount factor ($\beta(1-\sigma_f) = \beta(1-\sigma_w)$), and thus, they identically evaluate the future contributions of the wage on the match surplus.

As before, the equilibrium of the model is given by the pair (ω^*, θ^*) that jointly solves the wage curve and the job creation condition. The existence and uniqueness of equilibrium depends on – among other things – on the amount of disagreement in the agents' separation expectation. More formally, we establish the following proposition.

Proposition 8 (Existence and uniqueness of equilibrium under period-T-bargaining).
Under period-T-bargaining with biased-firm expectations, an equilibrium exists and is unique if the job-creation curve lies above the wage curve for $\theta \to 0$, i.e.

$$z-b-\frac{\kappa}{\beta}(1-\beta(1-\sigma_f)) > \gamma\left[z-b+\kappa\beta^{T-1}\frac{(1-\sigma_f)^T-(1-\sigma_w)^T}{(1+\Delta_{\lambda f})\sum_{t=1}^{T}\Big(\beta(1-\sigma_f)\Big)^{t-1}}\right],$$

and the wage curve is increasing, i.e.

$$\beta^{T-1}\left[(1-\sigma_w)^T-(1-\sigma_f)^T\right] \leq m(\theta)\frac{1+\Delta_{\lambda w}}{1-\epsilon_m(\theta)}\sum_{t=1}^{T}\Big(\beta(1-\sigma_w)\Big)^{t-1}.$$

[7]While the wage curve is the same as under rational expectations, the **equilibrium wage** may not be the same, because the value of θ can be different.

The first condition guarantees that the vertical intercept of the wage curve is below the intercept of the job creation condition. The second condition in the proposition ensures that the wage curve (weakly) increases with labor market tightness θ. This occurs when the firm is not too pessimistic relative to the worker. The intuition is straightforward. A pessimistic firm expects the match to end soon. In a tight market (high θ), this implies that the firm soon has to incur substantial hiring costs to find a new worker. This reduces the compensation that the firm is willing to pay to the worker for staying and saving current period hiring costs. In this case, the negative (second) term in the wage curve dominates the positive (first) term and, as a result, the wage declines with market tightness.

Lastly, we perform a comparative statics exercise to analyze the effects of firm's expectation biases on the equilibrium. An increase in the firm's vacancy filling bias $\Delta_{\lambda f}$ leads to a downward shift in the wage curve. As the firm expects to find a new worker more easily it pays a lower compensation to its worker for staying in the match. At the same time, the job creation condition shifts up because, due to the lower perceived recruiting costs, a higher wage is required for the firm to break even. The total effect on the wage is can be positive or negative but the labor market tightness unambiguously increases. As a result, a stronger optimistic bias in the firm's vacancy filling expectation leads more vacancy creation, higher market tightness, lower unemployment rate and a shorter unemployment duration.

An increase in the firm's separation bias $\Delta_{\sigma f} > 0$ leads to a downward shift of the job creation condition. The pessimistic firm expects a lower job duration, thus, it requires a lower wage to break even. The reaction of the wage curve depends on the bargaining horizon T. For a sufficiently low value of T, the increase in $\Delta_{\sigma f} > 0$ leads to a downward shift of the wage curve. The firm expects the worker to leave soon and, thus, it pays a lower compensation for saved hiring cost. As a result, stronger pessimistic bias in the firm's separation expectation leads to a lower wage, whereas the effect on vacancy creation and labor market tightness is ambiguous. In contrast, when bargaining occurs only infrequently (large T), then the wage curve shifts upward. The pessimistic firm strongly discounts the future, and thus, the worker is able to extract a larger share of the surplus via a higher wage. Consequently, the total effect on the equilibrium wage is ambiguous, but vacancy creation drops which leads to higher unemployment and longer unemployment duration. The results of the comparative statics exercise are succinctly presented in Table 1

3.3 Risk aversion

In another extension of the model, we relax the assumption of risk neutrality and allow workers to be risk averse. The purpose of this modification is to assess the extent to which risk aversion shapes the effects of expectation biases on wages. Concretely, we assume that worker's instantaneous utility function is given by $u(y)$ with $u'(y) > 0$, $u''(y) < 0$, $\lim_{y\to 0} u'(y) = \infty$, $\lim_{y\to\infty} u'(y) = 0$, where $y = \omega$, when the worker is employed, and $y = b$, when the worker is

			$T < T^*$			$T > T^*$		
Worker								
Job finding	$\Delta_{\lambda w} \uparrow$	$\Rightarrow$	$\omega \uparrow$	$\theta \downarrow$	$u \uparrow$	$\omega \uparrow$	$\theta \downarrow$	$u \uparrow$
Job separation	$\Delta_{\sigma w} \uparrow$	$\Rightarrow$	$\omega \uparrow$	$\theta \downarrow$	$u \uparrow$	$\omega \downarrow$	$\theta \uparrow$	$u \downarrow$
Firm								
Vacancy filling	$\Delta_{\lambda f} \uparrow$	$\Rightarrow$	$\omega ?$	$\theta \uparrow$	$u \downarrow$	$\omega ?$	$\theta \uparrow$	$u \downarrow$
Job separation	$\Delta_{\sigma f} \uparrow$	$\Rightarrow$	$\omega \downarrow$	$\theta ?$	$u ?$	$\omega ?$	$\theta \downarrow$	$u \uparrow$

Table 1: General equilibrium effects of expectation bias

unemployed. To keep the exposition concise, we refer the reader to the Appendix for the details of the extended model and the calculations.

Most importantly, we find that risk aversion tends to dampen the effect of worker's biases on wages. Using the Nash bargaining solution we establish that

$$\frac{\Delta\omega_{RA}}{\Delta\sigma_w} = \frac{\Delta\omega/\Delta\sigma_w}{\gamma + (1-\gamma)\left(1 - \epsilon_u \frac{u(\omega)-u(b)}{u'(\omega)\omega}\right)} \qquad \frac{\Delta\omega_{RA}}{\Delta\lambda_w} = \frac{\Delta\omega/\Delta\lambda_w}{\gamma + (1-\gamma)\left(1 - \epsilon_u \frac{u(\omega)-u(b)}{u'(\omega)\omega}\right)}$$

where $\left(\frac{\Delta\omega_{RA}}{\Delta\sigma_w}, \frac{\Delta\omega_{RA}}{\Delta\lambda_w}\right)$ and $\left(\frac{\Delta\omega}{\Delta\sigma_w}, \frac{\Delta\omega}{\Delta\lambda_w}\right)$ represent the reaction of wages to a change in the subjective separation and job finding probabilities – for risk aversion and risk neutrality, respectively. Moreover, $\epsilon_u \equiv \frac{\partial u'(\omega)}{\partial\omega}\frac{\omega}{u'(\omega)}$ is the elasticity of the marginal utility. Risk aversion implies that $\epsilon_u < 0$. Hence, the denominator in the expressions above is larger than unity. As a result, we obtain that $\left|\frac{\Delta\omega_{RA}}{\Delta\sigma_w}\right| < \left|\frac{\Delta\omega}{\Delta\sigma_w}\right|$ and $\frac{\Delta\omega_{RA}}{\Delta\lambda_w} < \frac{\Delta\omega}{\Delta\lambda_w}$. For an increasing degree of risk aversion, the denominator grows larger and leads to a smaller effect of a change in subjective expectations on the wage.

The intuition for this result is as follows. Risk aversion implies that workers associate a positive but declining value with each incremental increase in the wage. Formally, this can be observed from the partial derivative of the worker's surplus function (for period-T bargaining)

$$\frac{\partial E(\omega) - U}{\partial\omega} = u'(\omega)\sum_{t=1}^{T}\Big(\beta(1-\sigma_w)\Big)^{t-1} > 0 \qquad \frac{\partial^2 E(\omega) - U}{\partial\omega^2} < 0$$

The higher is the degree of risk aversion, the stronger is the decline in the extra value. Instead, under risk neutrality we have that $\frac{\partial^2 E(\omega)-U}{\partial\omega^2} = 0$. An increase in, say, the subjective job finding probability, λ_w, leads to an improvement of the worker's outside option and thus raises the threat point in the bargain. The firm reacts by paying a higher wage. However, it is optimal to raise the wage for risk averse workers by less than the wage for risk neutral workers. The reason is that risk averse workers perceive a smaller gain in the surplus for each marginal increase in the wage.

4 Efficiency

In this section, we investigate the implications of workers' expectation biases on the efficiency of equilibrium. As is well known, in the standard version of the model (with unbiased beliefs), the equilibrium is efficient iff the Hosios condition holds:

$$\gamma = (1 - \epsilon_m(\theta^*))$$

This condition is satisfied when the worker's bargaining power γ is equal to 1 minus the elasticity of the matching function, evaluated at the socially optimal level of market tightness θ^*. Notice that $1-\epsilon_m(\theta)$ is equivalent to the elasticity of the firm's vacancy filling probability $\frac{\partial m(\theta)/\theta}{\partial \theta} \frac{\theta}{m(\theta)/\theta}$.

In the next step, we first calculate the socially optimal level of labor market tightness, θ^*, and then we derive the conditions required for the decentralized equilibrium to be efficient. The objective of the social planner is to maximize social welfare which is given by the discounted stream of income:

$$\sum_{t=0}^{\infty} \beta^t \Big[z(1-u_t) + bu_t - \kappa v_t \Big]$$

The planner is subject to the same matching frictions as firms and workers. Therefore, when maximizing social welfare it cannot freely allocate workers to jobs but it choses the sequence of $\{u_{t+1}, \theta_t\}_t$ subject to the constraint

$$u_{t+1} = u_t + \sigma(1-u_t) - \theta_t q(\theta_t) u_t$$

In the appendix, we state the first-order conditions associated with the optimization problem. We collapse the first-order conditions and impose stationarity to obtain the condition which implicitly defines the socially efficient level of labor market tightness, θ^*.

$$\epsilon_m(\theta^*) \frac{m(\theta^*)}{\theta^*}(z-b) - \kappa m(\theta^*)(1-\epsilon_m(\theta^*)) = \kappa \left(\frac{1}{\beta} - 1 + \sigma \right) \tag{24}$$

In the next step, consider the model with biased worker beliefs. Under what conditions is the labor market tightness of the decentralized equilibrium equal to the socially optimal level? To address this question we first combine the wage schedule and the job creation condition to compute the equilibrium market tightness. Then we substitute the resulting expression into Equation (24). We refer the reader to the Appendix for the details. As a result of these calculations, we obtain the following "generalized Hosios condition" for the worker's bargaining power.

$$\gamma = \frac{(1-\epsilon_m(\theta^*)) \left(\frac{z-b}{\theta^*} + \kappa \right)}{\frac{z-b}{\theta^*} + \kappa \left(\frac{\sum_{t=1}^{T} (\beta(1-\sigma_w))^{t-1}}{\sum_{t=1}^{T} (\beta(1-\sigma))^{t-1}} (1+\Delta_{\lambda w}) + \beta^{T-1} \frac{(1-\sigma)^T - (1-\sigma_w)^T}{m(\theta^*) \sum_{t=1}^{T} (\beta(1-\sigma))^{t-1}} \right)} \tag{25}$$

It is straightforward to verify that in the absence of any bias – when $\sigma_w = \sigma$ and $\Delta_{\lambda w} = 0$ – this condition collapses to the standard Hosios condition $\gamma = (1 - \epsilon_m(\theta^*))$. The interpretation of the condition in (25) follows directly from the partial effects of the expectation biases on the wage schedule. For example, an optimistic job finding bias, $\Delta_{\lambda u} > 0$, leads to a higher bargained wage for each level of θ. To offset this effect, the worker's bargaining power must be lower than the level implied by the standard Hosios condition without biased beliefs. Likewise, a pessimistic job separation bias implies a lower (higher) wage for a sufficiently long (short) bargaining horizon, $T > T^*$ ($T < T^*$). A higher (lower) value of the worker's bargaining power is required to reach the socially optimal level of market tightness.

5 Labor market policy

In progress.

6 Conclusion

[To be completed] This paper introduces subjective expectations into a frictional labor market model and studies the implications of expectation biases for wage bargaining and equilibrium outcomes. As a key finding, the analysis reveals that in the presence of biased expectations the specific assumption about the frequency of wage bargaining becomes crucially important. Under the widely used assumption of period-by-period bargaining, then model generates counterfactual predictions regarding the effect of bias on wages. Instead, a wage setting process with less frequent bargaining is found to be empirically consistent.

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Appendix

To be added